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Measuring intellectual capital of science park performance for newly established science parks in Thailand

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Abstract

Most science parks (SP) have key performance indicators (KPIs) to indicate their performance. However, newly established science parks have not produced such measurable outputs to date. The aim of this study was to develop the measurement of intellectual capital aspects of science park performance for newly established science parks in Thailand using exploratory factor analysis (EFA). A Likert-type questionnaire survey was sent to a group of companies in the Federation of Thai Industries and 302 entrepreneurs and researchers in all science parks in Thailand from October to December, 2016. The four categories of intellectual capital (IC), namely, structural capital, human capital, relational capital, and innovation capital, were expanded into six factors: patent and innovation service, entrepreneurship development, infrastructure, partnership, officer qualification, and product design. This study contributes to more practice references for science parks managers for managing intellectual capital aspects of science park performance in newly established science parks in Thailand.

Introduction

Silicon Valley (CA, USA) was a pioneer in the development of science parks (SP) around the world. Originally known as Stanford University Science Park, Silicon Valley was started in the early 1950s. It was followed by Sophia Antipolis (France) in Europe in the 1960s and Tsukuba Science City (Japan) in Asia in the early 1970s. This trio represents the oldest and best-known science parks in the world. Today, there are over 400 science parks worldwide, and their number is still growing. At the top of the list comes the USA, which is reported to have more than 150 science parks. Japan comes next with 111 science parks. China began developing science parks in the mid-1980s and now has approximately 100, 52 of which were approved by the national government and the remainder of which were approved by local governments.

In brief, a science or technology park is a space, either physical or cybernetic, managed by a specialized team that provides value-added services and with the primary aim of increasing the competitiveness of its region or territory of influence. The space is intended to stimulate a culture of quality and innovation among its associated businesses and knowledge-based institutions, to organize the transfer of knowledge and technology from sources to companies and the marketplace, and to actively foster the creation of new and sustainable innovation-based companies through incubation and spin-off processes (Sanz, 2001).

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Allen (2007) described a science park development or maturation process in three generally applicable phases: initial planning and development (first generation), steady growth (second generation), and the mature phase (third generation). There is no consensus on the definition of a successful science park and its success. To define a science park's success, it is necessary to establish a reference framework, that is, a set of goals for measurement (Luger & Goldstein, 1991).

Notice that the indicators stated earlier have been developed mostly to evaluate the steady growth (second generation) and the mature phases (third generation). However, newly established SPs have yet to produce these measurable outputs. In this study, we developed a set of indicators for premature SPs using factor analysis and used it to assess pre-mature SPs in Thailand.

Literature Review

Intellectual Capital

Intellectual capital (IC) issues have undergone extraordinary development since the early 1990s. IC is a source of intangible (hidden) assets that often do not appear on the balance sheet (Edvinsson & Malone, 1994). Innovation organizations normally employ this approach to measure their capabilities (Edvinsson, 1997). The increasing difference between company market value and company book value has prompted academics and practitioners to consider the concept of intellectual capital as a key determinant of the process of value creation for shareholders, managers, and society as a whole (Edvinsson & Malone, 1997). The development of intellectual capital theory primarily evolved in the late 1980s and early 1990s. Edvinsson and Malone (1997) explained and identified IC components (human, organizational/structural and customer/social capital). Their respective models—“Intangible Assets Monitor” (IAM) (Sveiby, 1997); and “Skandia Navigator” (Edvinsson & Malone, 1997)—are representative of the assumptions, principles, and foundations of intellectual capital standard theory. Andriessen (2001) pioneered illustration of the basis of the intellectual capital standard theory and established the method in which intangible factors determine company success. IC has developed into a classification of the growth stage of intangible assets.

In the first stage, IC is grounded in the work of practitioners. The Skandia Navigator model was the basis for the first official publication of a corporate IC annual report in 1994. Skandia's IC Navigator was an attempt to show the firm's hidden value rather than its intangible assets. IC consists of a firm's knowledge assets and knowledge stocks (Brooking, 1996; Edvinsson & Malone, 1997; Edvinsson & Sullivan, 1996; Roos, Edvinsson, & Dragonetti, 1997; Stewart, 1997). IC is commonly considered in terms of the categories of human capital, structural capital, and relational capital (Edvinsson & Malone, 1997; Roos et al., 1997; Stewart, 1997; Sullivan, 1998). Nahapiet and Ghoshal (1998) describe IC as “a valuable resource and a capability for action based in knowledge and knowing”. The first stage of IC is determining the “grand theories” and creating awareness of the IC conceptual framework. Intellectual capital is important for managing sustainable competitive advantage (Petty & Guthrie, 2000).

The second stage of IC is investigating its impact on value creation and financial performance and making it visible through the creation of guidelines and standards (Petty & Guthrie, 2000). The third stage of IC drives value creation in products and services to customers and all stakeholders and not only monetary gain (Dumay, 2009).

Finally, the fourth stage concentrates on building strong economic, social, and environmental eco-systems through research on the IC eco-systems of cities and nations (Dumay & Garanina, 2013).

Science Park and Performance

Most SPs are evaluated in terms of economic performance, innovative activities, university growth and profile, patenting activity, relationships between firms and public research organizations, and knowledge spillovers.

Economic performance indicators include employment growth (Ferguson & Olofsson, 2004; Löfsten & Lindelöf, 2001, 2002, 2003) sales growth (Chen & Huang, 2004; Lee & Yang, 2000; Löfsten & Lindelöf, 2001, 2002, 2003), employment turnover per firm (Kihlgren, 2003; Vedovello, 1997), number of employees per firm (Colombo & Delmastro, 2002; Löfsten & Lindelöf, 2002; Quintas, Wield, & Massey, 1992; Vedovello, 1997; Yang, Motohashi, & Chen, 2009), and sales growth, labor productivity, and turnover per employee-year (Hu, 2007; Kihlgren, 2003; Lee & Yang, 2000).

Innovative activity indicators include new products/services launched (Siegel, Westhead, & Wright, 2003; Westhead, 1997), on-park firms performing R&D activities (Vedovello, 1997), type of R&D activity (Vedovello, 1997), R&D expenditure (Leyden, Link, & Siegel, 2008; Siegel et al., 2003; Westhead, 1997; Yang et al., 2009), R&D intensity (Fukugawa, 2006; Lee & Yang, 2000; Westhead, 1997; Yang et al., 2009), researchers/engineers among total workers (Colombo & Delmastro, 2002; Siegel et al., 2003; Vedovello, 1997; Westhead, 1997), employees with graduate degrees (Colombo & Delmastro, 2002), and firms involved in R&D projects (Colombo & Delmastro, 2002).

Universities' growth and profile indicators include purchased R&D services (Colombo & Delmastro, 2002), number of patent applications (Link & Scott, 2003; Siegel et al., 2003; Yang et al., 2009), number of patent applications per year (Squicciarini, 2008; Westhead, 1997), and number of publications (Link & Scott, 2003).

Relationships between firms and public research organizations are measured using indicators such as percentage of firms having links with higher education institutes (HEIs) (Malairaja & Zawdie, 2008; Vedovello, 1997), hiring of doctoral graduates and scholars (Link & Scott, 2003; Malairaja & Zawdie, 2008; Vedovello, 1997), performing joint research with firms (Fukugawa, 2006; Malairaja & Zawdie, 2008), and formal and informal links and number of links between firms and public research organizations (Bakouros, Mardas, & Varsakelis, 2002; Malairaja & Zawdie, 2008; Phillimore, 1999; Quintas et al., 1992; Vedovello, 1997). Science parks show significant growth when linked to universities and other institutions (Link & Scott, 2003).

Science park tenants exhibit comparatively better performance in patenting activity (Colombo & Delmastro, 2002; Squicciarini, 2008), average cost per patent, or R&D expenditure per number of patents (Yang et al., 2009).

Indicators of knowledge spillover that enhance innovation and competitiveness include number of publications (Albahari, Catalano, & Landoni, 2013; Bigliardi, Dormio, Nosella, & Petroni, 2006; Link & Scott, 2003), firms with copyright (Colombo & Delmastro, 2002), and number of copyrights (Siegel et al., 2003; Westhead, 1997).

Most science parks have a positive impact on university growth and profile. The parks enable universities to increase their numbers of publications and patents, facilitate transfer of technologies, and simplify placement of graduates. Many firms purchase R&D services from higher education institutions (Colombo & Delmastro, 2002), which increases universities' numbers of patent applications (Link & Scott, 2003; Siegel et al., 2003; Yang et al., 2009), numbers of patent applications per year (Squicciarini, 2008; Westhead, 1997), and numbers of publications (Link & Scott, 2003).

Notice that the indicators mentioned earlier involve established SPs. To measure a premature SP, we need to develop new indicators, compile them into an index, and test their performance as an evaluation tool.

To obtain the necessary indicators for evaluating premature science parks, the concept of intellectual capital is used. Intellectual capital includes all non-tangible resources that are attributed to an organization and contribute to the delivery of the organization's value statement. We will investigate whether science parks have intangible resources. Intangible resources can be split into four components: human capital, structural capital, relational capital, and innovation capital.

Methods

A questionnaire survey was sent to 960 companies listed on the board of the Federation of Thai Industries and companies working with the Science Park Promotion Agency (13 science parks and the Thailand Science Park). The companies represent various industries: air-conditioning and refrigeration, printing and packaging, cosmetics, biotech, chemicals, dietary supplements, medical and health devices, pharmaceuticals, plastics, herbal products, textile, foundry, pulp and paper, rubber-based, and renewable energy. The power producing, auto parts and gas manufacturing sectors were excluded from this survey because of their specialization and the science park's cluster and disclosure compliance requirements for the sector. After the initial mailing, three reminders were sent and telephone calls were made to improve the response rate. A total of 354 questionnaires were returned; 52 questionnaires were not complete, leaving 302 questionnaires and providing a response rate of 31 percent.

Data were first obtained from content analysis of surveys with experts in SPs. An evaluation using the index of item-objective congruence (Hambleton, Swaminathan, Algina, & Coulson, 1978; Rovinelli & Hambleton, 1977) is a process by which content experts rate individual items based on the degree to which they measure specific objectives listed by the researcher. More specifically, a content expert will evaluate each item by giving the item a rating of 1 (clearly measuring), −1 (clearly not measuring), or O (degree to which it measures the content area is unclear) for each objective. Furthermore, if the IOC is between 0.50 and 1.00, then the item has validity. However, if the IOC is below 0.50, then the item should be adjusted or cut off.

Then, quantitative data were obtained through a literature review and questionnaire surveys with experts, following an IC method of evaluation with four categories (structural capital, human capital, relational capital, and innovation capital) and 79 sub criteria. Each of the KPIs was rated to determine whether it was relevant to SP performance using a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). Then, exploratory factor analysis was used to reduce factors and reach a new arrangement. Comrey and Lee (1992) suggested that a sample size of 300 is acceptable. This sample was classified into two groups: first, the experts on SPs, such as SP directors or managers (Thailand Science Park (TSP), Science Park Promotion Agency (SPA), Khon Kaen University, Prince of Songkla University, Chiang Mai University, and the National Science and Technology Development Agency (NSTDA)), and second, a group of companies in the Federation of Thai Industries and researchers that may use SPs.

The list of IC line items considered in this paper was derived from past studies relating to the IC concept. The evaluation approach based on input relied on the Intellectual Capital model (Edvinsson, 1997). Table 1 shows the Intellectual Capital components and the related KPIs tailored for science parks in Thailand. The instrument was based on Comacchio and Bonesso (2012), Science Park Promotion Agency (SPA) and Thailand Science Park (TSP) and incorporated various items by Chen, Zhu, and Yuan Xie (2004), Wu, Chen, and Chen (2010), and Günther (2010) as shown in Table 1.

Results and Discussion

When the questionnaire was tested for reliability, the value of Cronbach's alpha (0.978) was greater than 0.8, indicating strong reliability. The most commonly used procedure for determining the number of initial factors to be extracted is the rule known as the Kaiser or the eigenvalue criterion (Kim & Mueller, 1978). The eigenvalue is a statistic for each factor that indicates the amount of variance in the pool of initial items that the factor explains. In this study, as recommended by Kaiser (1960), factors that have an eigenvalue greater than 1 are treated as relevant to select other factors. In this study, we used eigenvalues greater than 2 for only strong factor values (Table 2). Before proceeding to the results of the factor analysis, two tests justifying the appropriateness of factor analysis were reported: (1) the Bartlett test of sphericity and (2) the Kaiser-Meyer-Olkin measure (KMO) (Hair, Anderson, Tatham, & William, 1995; Tabachnick & Fidell, 2007). The data of this study we shown to be significant according to the Bartlett test of sphericity. The KMO measure of sampling adequacy was 0.918. Kaiser (1974) guidelines on the interpretation of KMO values state that values greater than 0.90

Table 1
KPI Intellectual capital of a science park

Structure capital (SC)		Human capital (HC)		Relational capital (RC)		Innovation capital (INC)	
Code	IC element	Code	IC element	Code	IC element	Code	IC element
SC1	The duration of the science park's establishment.[3]	HC1	The science park has permanent staff.[3]	RC1	The science park has partners.[3]	INC1	The science park has new products and new services.[12]
SC2	There is a research laboratory in the science park.[3]	HC2	The science park has temporary staff.[3]	RC2	The science park has new partners each year.[3]	INC2	The science park has an increase in patents per employee.[1]
SC3	There are high technology companies located in the science park.[3]	HC3	The science park has contract project staff.[3]	RC3	The science park has foreign partners.[3]	INC3	The science park has increasing technology development.[1]
SC4	There are start-up companies located in the science park.[8]	HC4	The science park has staff who are experts in science, technology, and innovation.[3]	RC4	The science park has research and development partners.[3]	INC4	The science park has revenue from royalties/patents and brands.[11]
SC5	The science park hosts an activity area for the incubators.[3]	HC5	The science park employs graduate staff.[3]	RC5	A general company uses results of research from the science park for commercialization.[13,14]	INC5	The science park has a portfolio of intellectual property applied each year.[13]
SC6	The science park hosts research activities for incubators.[3]	HC6	The science park employs staff with master's degrees.[3]	RC6	A startup company uses results of research from the science park for commercialization each year.[13]	INC6	The science park has revenues from intellectual property for commercialization.[6]
SC7	The science park has fixed assets (such as factories and machinery).[3]	HC7	The science park employs PhD-qualified staff.[5]	RC7	Participant satisfaction is involved in the technology transfer of the science park.[3]	INC7	The science park has a license patent to give to licensing start-up companies.[10]
SC8	The science park has the necessary infrastructure.[3]	HC8	The science park has experienced executive staff.[5]	RC8	Customer complaints are treated by the science park.[3]	INC8	The science park has a license patent to give to licensing companies.[10]
SC9	The science park has activities for technology transfer.[3]	HC9	The science park has experienced research staff.[5]	RC9	The science park has customers using its services.[3]	INC9	The science park has training on intellectual property (e.g., patents).[13]
SC10	The science park has invested in basic research and applied research.[3]	HC10	The science park has employee training.[4]	RC10	The science park has suppliers to provide services.[4]	INC10	The science park has revenues from a center for design innovation services.[13]
SC11	The science park is near an institute of higher education.[2]	HC11	The science park develops staff working on research and development.[11]	RC11	There is cooperative research between organizations and the science park.[7]	INC11	The science park has a center of intellectual property management services available.[13]
SC12	The science park has partnered with a local laboratory.[13]	HC12	The science park pays the cost of training and staff development.[3]	RC12	The science park has increased involvement in innovative activities with external innovation groups to expand market share, reduce costs, and share resources.[1]	INC12	The science park develops and improves the system of intellectual property (patent search database).[13]
SC13	The science park has old entrepreneurs join its business incubator program.[13,14]	HC13	The science park has a rate of admission-reassigned per year.[3]	RC13	Entrepreneurs consult the intellectual property of the science park.[13]	INC13	The science park provides management of intellectual property to the industry (IP for industry).[13]
SC14	The science park has new start-ups join its accelerated growth program.[13]	HC14	The science park has senior staff.[3]	RC14	Companies participate in services such as intellectual property management, design innovation services, laboratory services, industrial cooperation, and other services of the science park.[13]	INC14	The science park creates awareness about intellectual property.[13]
SC15	The science park has old businesses join its accelerated growth program.[13]	HC15	The science park has employee satisfaction in environmental work.[3]	RC15	The science park has participants in knowledge-based learning.[13]		

SC16	The science park has entrepreneurs nurture the management of intellectual property and design innovation.[13]	HC16	The science park has employee training courses in new innovation.[9]	RC16	The science park has been jointly organization to benefit the technology industry.[13]
SC17	The science park serves entrepreneurs in the Office of Industrial Cooperation and in other services.[13]			RC17	The science park serves customers in a university.[13]
SC18	The science park has research on building a business activity at both national and regional levels.[13]			RC18	The science park provides services for customers outside the university.[13]
SC19	The science park has a team to create business-class technology activities in universities.[13]			RC19	The science park has joint ventures with organizations participating in its programs or services.[13]
SC20	The science park has a team to create business-class technology activity at the regional level.[13]				
SC21	The science park has a team to create business-class technology activity at the national level.[13]				
SC22	The science park has new data in the database.[13]				
SC23	The science park has up-to-date information.[13]				
SC24	The science park activity service has used word of mouth to communicate with entrepreneurs.[13]				
SC25	The science park has activities to raise awareness and public relations with the customer.[13]				
SC26	The science park has revenues generated from the provision of laboratory services.[13]				
SC27	The science park has benefit to the customer.[3]				
SC28	The number of packaging designs produce by the science park.[13]				
SC29	The number of product designs produced by the science park.[13]				
SC30	The number of logo designs produced by the science park.[13]				

Sources: Chen et al., 2004[1]; Colombo & Delmastro, 2002[2]; Comacchio & Bonesso, 2012[3]; Gogan & Draghici, 2013[4]; Herrero-Villa, Castro, & Molero, 2014[5]; Kijek, 2012[6]; Koch, Leitner, & Bomemann, 2000[7]; Löfsten & Lindelöf, 2005[8]; Mariz-Perez, Teijeiro-Alvarez, & Garcìa-Alvarez, 2012[9]; National Innovation Agencies (NIA)[10]; Petty, & Guthrie, 2000[11]; Schoenecker & Swanson, 2002[12]; Science Park Promotion Agency (SPA)[13]; Thailand Science Park (TSP)[14]

Table 2
Rotated component matrix for the six-factor solution

IC item	Factor					
	1	2	3	4	5	6
Group 1: Science Park Performance in Patent and Innovation Services						
The science park is to provide the management of intellectual property to industry (IP for industry).	0.789					
The science park is to develop and improve the system of intellectual property (patent search database).	0.765					
The science park is to serve customers outside the university.	0.745					
The science park has joint ventures with organizations participating in its programs or services.	0.745					
The science park has participants in knowledge-based learning.	0.740					
The science park works jointly with organizations to benefit the technology industry.	0.726					
The science park is to create awareness about intellectual property.	0.713					
The science park serves customers in a university.	0.704					
The science park has center of intellectual property management services available.	0.699					
The science park has increasing technology development.	0.683					
The science park has a portfolio of intellectual property applied each year.	0.679					
The science park has training on intellectual property.	0.674					
The science park uses revenues from intellectual property for commercialization.	0.666					
The science park has revenue from royalties/patents and brands.	0.661					
The science park has suppliers to provide services.	0.661					
The science park has customers to use services.	0.637					
Entrepreneurs consult the intellectual property of the science park.	0.615					
There is cooperative research between organizations and the science park.	0.614					
The science park has increased involvement in innovative activities with external innovation groups to expand market share, reduce costs, and share resources.	0.587					
Companies participate in services such as intellectual property management, design innovation services, laboratory services, industrial cooperation, and other services.	0.575					
The science park has employee training courses in new innovation.	0.567					
The science park has a license patent to give to licensing companies.	0.536					
The science park has employee training.	0.535					
Participants involved in the science park's technology transfer are satisfied.	0.525					
The science park has experienced executive staff.	0.521					
The science park has activities to raise awareness and public relations with customers.	0.521					
The science park has a license patent for licensing start-up companies.	0.521					
The science park has revenues from center for design innovation services.	0.520					
The science park has employee satisfaction in environmental work.	0.509					
The science park has expert staff in science, technology, and innovation.	0.501					
Group 2: Science Park Performance in Entrepreneurship Development						
Entrepreneurs nurture the management of intellectual property and design innovation in the science park.		0.744				
The science park has selection research for building business activity at both national and regional levels.		0.693				
The science park has a team to create business-class technology activity at the regional level.		0.693				
The science park serves entrepreneurs in the Office of Industrial Cooperation and other services.		0.689				
The science park has new data in its database.		0.679				
The science park has a team to create business-class technology activity at the national level.		0.677				
The science park has a team to create business-class technology activity in universities.		0.664				
The science park has old entrepreneurs joining its business incubator program.		0.622				
The science park has new start-ups joining its accelerated growth program.		0.619				
The science park has up-to-date information.		0.589				
The science park has old businesses joining its accelerated growth program.		0.576				
The science park activity service uses word-of-mouth to contact entrepreneurs.		0.560				
Group 3: Science Park Performance in Infrastructure						
The science park has the necessary infrastructure.			0.737			
The science park hosts research activity for incubators.			0.732			
Start-up companies are located in the science park.			0.642			
The science park has activities for technology transfer.			0.640			
High technology companies are located in the science park.			0.639			
The science park has fixed assets (such as factories, machinery).			0.634			
There is a research laboratory in the science park.			0.632			
The science park hosts an activity area for incubators.			0.632			
The science park partners with local laboratories.			0.583			
The science park has invested in basic research and applied research.			0.551			
The science park has area benefit to the customer.			0.511			
Group 4: Science Park Performance in Partnership						
The science park has partners.				0.804		
The science park has foreign partners.				0.727		

Table 2 (*continued*)

IC item	Factor					
	1	2	3	4	5	6
The science park has new partners each year.				0.723		
The science park has research and development partners.				0.712		
Group 5: Science Park Performance in Officer Qualification						
The science park employs PhD-qualified staff.					0.776	
The science park employs staff with master's degrees.					0.753	
The science park has experienced research staff.					0.693	
The science park develops staff working on research and development.					0.530	
Group 6: Science Park Performance in Product Design						
The number of logo designs produced by the science park.						0.760
The number of print media designs produced by the science park.						0.690
The number of packaging designs produce by the science park.						0.677
The science park has revenues generated from the provision of laboratory services.						0.506
Eigenvalues	16.339	8.884	8.565	5.137	4.916	4.154
Percentage of variance	20.682	11.245	10.842	6.503	6.223	5.269
Cumulative percentage	20.682	31.927	42.769	49.271	55.494	60.753
Extraction Method: Principal Component Analysis.						
Rotation Method: Varimax with Kaiser Normalization.						

are considered “marvelous” and those between 0.80 and 0.89 are “meritorious”. Hence, it was concluded that factor analysis was appropriate for the data on the availability of IC item information.

The initial KPIs of the 79 IC items were divided into four categories: structural capital (SC), human capital (HC), relational capital (RC), and innovation capital (INC). Principal component analysis with varimax rotation was conducted to extract common factors. Items with factor loadings greater than 0.5 were selected to ensure a stable factor structure with adequate sample size and ratio of participants and variables (Ferguson & Cox, 1993). Fourteen items were eliminated. Sixty-five residual items were arranged into six factors based on the size of loadings in statistical analysis. The pattern matrix produced IC items with cross loadings; thus, it was necessary to determine which of the six factors the items identified with most strongly. This was done by examining the factor loadings in the factor matrix. The loadings are correlations between the item and the other components. The higher its loading, the more a variable belongs to that component, which yielded only six factors as shown in Table 2.

Based on the study of science park performance, the six factors were given the following names: The first factor consisted of 30 variables and was called science park performance in patent and innovation service. Items were mostly categorized from the group of 12 items of relational capital, 12 items of innovation capital, 5 items of human capital, and 1 item of structural capital. The second factor comprised 12 variables and was called science park performance in entrepreneurship development. The items categorized were only from the group of 12 items from structural capital. The third factor comprised 11 variables and was called science park performance in infrastructure. All items were categorized from the group of 11 items of structural capital. The fourth factor identified four variables and was called science park performance in partnership. All items were categorized from the group of four items from relational capital. The fifth factor identified four variables and was called science park performance in officer qualification. All items were categorized from the group of four items from human capital. The sixth factor identified four variables and was called science park performance in product design. All items were categorized from the group of four items from structural capital. These six factors, respectively, explained 20.682 percent, 11.245 percent, 10.842 percent, 6.503 percent, 6.223 percent, and 5.259 percent of the intellectual capital of science park performance for newly established science parks in Thailand. The six factors of the IC items accounted for 60.753 percent of the variance (Table 2).

Entrepreneurship Development; There is a lack of strong investment of this in Thailand SP itself. Most of the funds used in SP programs are diverted toward the development of hard infrastructure (office buildings) rather than the soft infrastructure such as the entrepreneurial development. The equipment being invested in the infrastructure is basic and not highly tailored toward a particular industry which is a specialty of the SP.

Infrastructure; In Thailand infrastructure has not successfully connected science and technology with business knowledge. Most of the investments in infrastructure are basic which do not leverage advance innovation and technology transfer.

Patent and innovation service; Researchers in the university and SPs in Thailand have a KPI involving research papers and output for petty patents only not connected to research problems from industry or business, most research has not been commercialized, and nowadays, SPs have no database to use in matchmaking businesses and entrepreneurs. There are only few patents registered with the Thai Department of Intellectual Property (DIP) in Thailand and most of these belong to foreigners.

Partnership; Most SPs in Thailand are newly established and do not have a strong relationship with either domestic or foreigner partners. As a result of this weak relationship, research projects from these SPs do not yet demonstrate their high applicability to industry.

Officer Qualification; In Thailand, masters and doctoral degrees do not have skills that match industry purpose.

Most of the time, they are skillful academically but lacking in creativity in commercial R&D. Low compensation and remuneration are common in Thai SPs, making them incapable of attracting high profile staff.

Product design; Product design and packaging design are one of the key elements in developing and marketing a new product based on R&D. The product and packing design should be user friendly, brand reflecting, and serving a technical purpose. For technical purposes, packaging is crucial for food products which are a main area for Thai SPs because the design influences both customer perception and the shelf life of the products.

The results of the current study of SPs indicated that to achieve all important criteria/KPIs, an SP should specialize in a field/industry in order to set up an effective/practical entrepreneur and a startup development program; strengthening R&D capabilities to create competitive advantages in technology following the filing of intellectual property; and setting up the proper infrastructure to facilitate creative/exchanged ideas, and to fast forward the prototyping stage at low cost. All of these provide the right support for SP customers.

Conclusion and Recommendation

The study revealed that the intellectual capital aspects of science park performance for newly established science parks in Thailand were divided into six groups: patent and innovation service, entrepreneurship development, infrastructure, partnership, officer qualification, and product design. This study should interest academics and business practitioners alike because the development of KPIs by looking through the lens of intellectual capital can lead to future competitive advantage of greater value than the traditional tasks of deploying an organization's physical and capital assets. Science parks should make IC-based management a requirement for evaluation by assigning KPI targets to facets of intellectual capital development. For example, science parks can have each employee create new ideas to learn that the organization has intangible assets. This research contribution may benefit academics and science park managers, as it may provide a basis for evaluating innovative institutes using intellectual capital in other fields, countries and/or industries. However, given this work's limited sample size, the perspective of IC may differ by industry and respondent.

Finally, a science park manager must have interest in the field of intellectual capital and find useful KPIs for constructing intellectual capital in the organization, developing the six proposed components and using the survey items as a measurement tool for analyzing the competitiveness of the organization's intellectual capital. Further research may investigate KPIs for the intellectual capital of specific industry sectors/types. Another research opportunity is to investigate how science park IC should be measured in developed and developing countries.

Conflict of interest

There is no conflict of interest.

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References

Albahari, A., Catalano, G., & Landoni, P. (2013). Evaluation of national science park systems: A theoretical framework and its application to the Italian and Spanish systems. *Technology Analysis & Strategic Management, 25*(5), 599–614.

Allen, J. (2007). *Third generation science parks*. Manchester, UK: Manchester Science Parks.

Andriessen, D. (2001). Weightless wealth: Four modifications to standard IC theory. *Journal of Intellectual Capital, 2*(3), 204–214.

Bakouros, Y. L., Mardas, D. C., & Varsakelis, N. C. (2002). Science park, a high tech fantasy: An analysis of the science parks in Greece. *Technovation, 22*(2), 123–128.

Bigliardi, B., Dormio, A. I., Nosella, A., & Petroni, G. (2006). Assessing science parks' performances: Directions from selected Italian case studies. *Technovation, 26*(4), 489–505.

Brooking, A. (1996). *Intellectual capital: Core asset for the third millennium*. London, UK: International Thomson Business Press.

Chen, C. J., & Huang, C. C. (2004). A multiple criteria evaluation of high-tech industries for the science-based industrial park in Taiwan. *Information & Management, 41*, 839–851.

Chen, J., Zhu, Z., & Yuan Xie, H. (2004). Measuring intellectual capital: A new model and empirical study. *Journal of Intellectual Capital, 5*(1), 195–212.

Colombo, M., & Delmastro, M. (2002). How effective are technology incubators?: Evidence from Italy. *Research Policy, 31*, 1103–1122.

Comacchio, A., & Bonesso, S. (2012). *Performance evaluation for knowledge transfer organizations: Best European practices and a conceptual framework*. Rijeka, Croatia: Intech Open Access Publisher.

Comrey, A. L., & Lee, H. B. (1992). *A first course in factor analysis* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum.

Dumay, J. (2009). Intellectual capital measurement: A critical approach. *Journal of Intellectual Capital, 10*(2), 190–210.

Dumay, J., & Garanina, T. (2013). Intellectual capital research: A critical examination of the third stage. *Journal of Intellectual Capital, 14*(1), 10–25.

Edvinsson, L. (1997). Developing intellectual capital at Skandia. *Long Range Planning, 30*(3), 320–373.

Edvinsson, L., & Malone, M. (1994). *Visualizing intellectual capital in Scandia*. Fairfield, CA: Scandia 203.

Edvinsson, L., & Malone, M. S. (1997). *Intellectual capital: Realizing your company's true value by finding its hidden brainpower*. New York, NY: Harper Business.

Edvinsson, L., & Sullivan, P. (1996). Developing a model for managing intellectual capital. *European Management Journal, 14*(4), 356–364.

Ferguson, E., & Cox, T. (1993). Exploratory factor analysis: A users' guide. *International Journal of Selection and Assessment, 1*(2), 84–94.

Ferguson, R., & Olofsson, C. (2004). Science parks and the development of NTBFs location, survival and growth. *Journal of Technology Transfer, 29*, 5–17.

Fukugawa, N. (2006). Science parks in Japan and their value-added contributions to new technology-based firms. *International Journal of Industrial Organization, 24*(2), 381–400.

Gogan, L. M., & Draghici, A. (2013). A model to evaluate the intellectual capital. *Procedia Technology, 9*, 867–875.

Günther, T. (2010). Accounting for innovation: Lessons learnt from mandatory and voluntary disclosure. In *Innovation and international corporate growth* (pp. 319–332). Berlin, Germany: Springer.

Hair, J. F., Jr., Anderson, R. E., Tatham, R. L., & William, C. (1995). *Multivariate data analysis with readings*. Englewood Cliffs, NJ: Prentice-Hall.

Hambleton, R. K., Swaminathan, H., Algina, J., & Coulson, D. B. (1978). Criterion-referenced testing and measurement: A review of technical issues and developments. *Review of Educational Research, 48*(1), 1–47.

Herrero-Villa, M. J., Castro, S. L., & Molero, J. (2014). An approach for Sigrid1 validation methodology as an evaluation method for science parks management: The case of the Madrid Science Park and Park of the University Carlos III of Madrid. *American International Journal of Social Science, 3*(5), 72–82.

Hu, A. G. Z. (2007). Technology parks and regional economic growth in China. *Research Policy, 36*, 76–87.

Kaiser, H. F. (1960). The application of electronic computers to factor analysis. *Educational and Psychological Measurement, 20*(1), 141–151.

Kaiser, H. F. (1974). An index of factorial simplicity. *Psychometrika, 39*(1), 31–36.

Kihlgren, A. (2003). Promotion of innovation activity in Russia through the creation of science parks: The case of St. Petersburg (1992–1998). *Technovation, 23*(1), 65–76.

Kijek, T. (2012). *Innovation capital and its measurement*. Retrieved from https://www.ceeol.com/content-files/document-171556.pdf.

Kim, J. O., & Mueller, C. W. (1978). *Introduction to factor analysis*. Beverly Hills, CA: Sage Publications.

Koch, G., Leitner, K. H., & Bornemann, M. (2000). Measuring and reporting intangible assets and results in a European contract research organization. Retrieved from https://www.researchgate.net/profile/Manfred_Bornemann/publication/270475758_Measuring_and_reporting_intangible_assets_and_results_in_a_European_Contract_Research_Organization/links/54aba2ec0cf25c4c472f80d5.pdf.

Lee, W. H., & Yang, W. T. (2000). The cradle of Taiwan high technology industry development Hsinchu Science Park (HSP). *Technovation, 20*, 55–59.

Leyden, D. P., Link, A. N., & Siegel, D. S. (2008). A theoretical and empirical analysis of the decision to locate on a university research park. *IEEE Transactions on Engineering Management, 55*(1), 23–28.

Link, A., & Scott, J. T. (2003). US science parks: The diffusion of an innovation and its effects on the academic missions of universities. *International Journal of Industrial Organization, 21*, 1323–1356.

Löfsten, H., & Lindelöf, P. (2001). Science parks in Sweden: Industrial renewal and development? *R & D Management, 31*(3), 309–322.

Löfsten, H., & Lindelöf, P. (2002). Science parks and the growth of new technology-based firms-Academic-industry links, innovation and markets. *Research Policy, 31*(6), 859–876.

Löfsten, H., & Lindelöf, P. (2003). Science park location and new technology-based firms in Sweden: Implications for strategy and performance. *Small Business Economics, 20*(3), 245–258.

Löfsten, H., & Lindelöf, P. (2005). R&D networks and product innovation patterns—academic and non-academic new technology-based firms on science parks. *Technovation, 25*(9), 1025–1037.

Luger, M. I., & Goldstein, H. A. (1991). *Technology in the garden*. Chapel Hill, NC: UNC Press.

Malairaja, C., & Zawdie, G. (2008). Science parks and university-industry collaboration in Malaysia. *Technology Analysis & Strategic Management, 20*(6), 727–739.

Mariz-Perez, R. M., Teijeiro-Alvarez, M. M., & Garcìa-Alvarez, M. T. (2012). The relevance of human capital as a driver for innovation. *Cuadernos De Economia, 35*(98), 68–76.

Nahapiet, J., & Ghoshal, S. (1998). Social capital, intellectual capital, and the organizational advantage. *Academy of Management Review, 23*(2), 242–266.

Petty, R., & Guthrie, J. (2000). Intellectual capital literature review: Measurement, reporting and management. *Journal of Intellectual Capital, 1*(2), 155–176.

Phillimore, J. (1999). Beyond the linear view of innovation in science park evaluation: An analysis of western Australian technology park. *Technovation, 19*(11), 673–680.

Quintas, P., Wield, D., & Massey, D. (1992). Academic-industry links and innovation: Questioning the science park model. *Technovation, 12*(3), 161–175.

Roos, J., Edvinsson, L., & Dragonetti, N. C. (1997). *Intellectual capital: Navigating the new business landscape*. London, UK: Palgrave Macmillan.

Rovinelli, R. J., & Hambleton, R. K. (1977). On the use of content specialists in the assessment of criterion-referenced test item validity. *Dutch Journal of Educational Research, 2*, 49–60.

Sanz, L. (2001). *From technology parks to learning villages: A technology park model for the global society.* Paper presented at XVIII IASP World Conference on Science & Technology Parks, Bilbao, Spain.

Schoenecker, T., & Swanson, L. (2002). Indicators of firm technological capability: Validity and performance implications. *IEEE Transactions on Engineering Management, 49*(1), 36–44.

Siegel, D. S., Westhead, P., & Wright, M. (2003). Assessing the impact of university science parks on research productivity: Exploratory firm-level evidence from the United Kingdom. *International Journal of Industrial Organization, 21*(9), 1357–1369.

Squicciarini, M. (2008). Science Parks' tenants versus out-of-Park firms: Who innovates more? A duration model. *Journal of Technology Transfer, 33*(1), 45–71.

Stewart, T. A. (1997). *Intellectual capital: The new wealth of organizations*. New York, NY: Doubleday Dell.

Sullivan, P. H. (1998). *Profiting from intellectual capital: Extracting value from innovation*. New York, NY: John Wiley & Sons.

Sveiby, K. E. (1997). *The new organizational wealth: Managing & measuring knowledge-based assets*. San Francisco, CA: Berrett-Koehler Publishers.

Tabachnick, B. G., & Fidell, L. S. (2007). *Using multivariate statistics* (5th ed.). Boston, MA: Pearson.

Vedovello, C. (1997). Science parks and university-industry interaction: Geographical proximity between the agents as a driving force. *Technovation, 17*(9), 491–502.

Westhead, P. (1997). R&D inputs and outputs of technology-based firms located on and off science parks. *R & D Management, 27*(1), 45–62.

Wu, H. Y., Chen, J. K., & Chen, I. S. (2010). Innovation capital indicator assessment of Taiwanese Universities: A hybrid fuzzy model application. *Expert Systems with Applications, 37*(2), 1635–1642.

Yang, C. H., Motohashi, K., & Chen, J. R. (2009). Are new technology-based firms located on science parks really more innovative? *Research Policy, 38*, 77–85.